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Challenges in Long-Term National Strategic Initiative Development for Advanced Technologies

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The Next Generation Air Transportation System (NextGen) represents the transformation of the National Airspace System, including our national system of airports, using 21st century technologies to ensure future safety, capacity and environmental needs are met. NextGen will be realized through investments in research and development, technologies, operational changes, and the coordinated efforts of private industry and federal NextGen Partner Agencies, including the Federal Aviation Administration (FAA); the Departments of Transportation (DOT), Defense (DOD), Homeland Security (DHS), and Commerce (DOC); the National Aeronautics and Space Administration (NASA); and the White House Office of Science and Technology Policy (OSTP). In order to accomplish the NextGen vision a broad range of advanced technologies will be required that will push the state of the art not only in the field of aviation, but in basic sciences, and other disciplines and industries. In order to fully assess the investment options both within the NextGen community and in other relevant fields and industries a common evaluation strategy is required. This paper will propose a set of universal metrics to help translate and normalize technology transfer benefits to help best optimize government, industry, and academia investments.

I. Background

Developing the Next Generation Air Transportation System is a complex undertaking that requires both investment and regulatory decisions be made by a number of parties where no single party can assure the successful outcome. For example, the air navigation service provider must modernize its infrastructure, and aircraft operators such as airlines must equip to operate in the new environment. In addition, because of the high level of potential consequences, safety procedures and regulations must be developed to not only operate in a new environment but to transition from the existing one to it. To make NextGen a reality, the JPDO partner agencies must operate an R&D program to produce needed technologies for all the key areas. This is illustrated in Figure 1 below.

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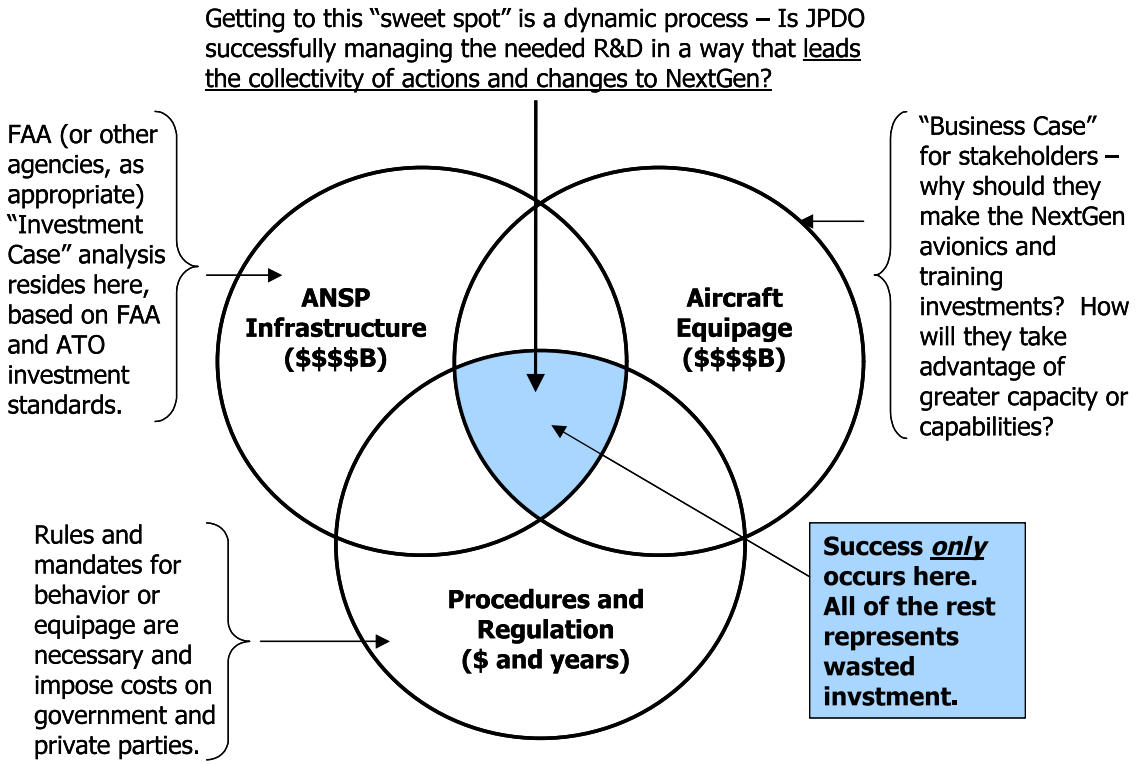
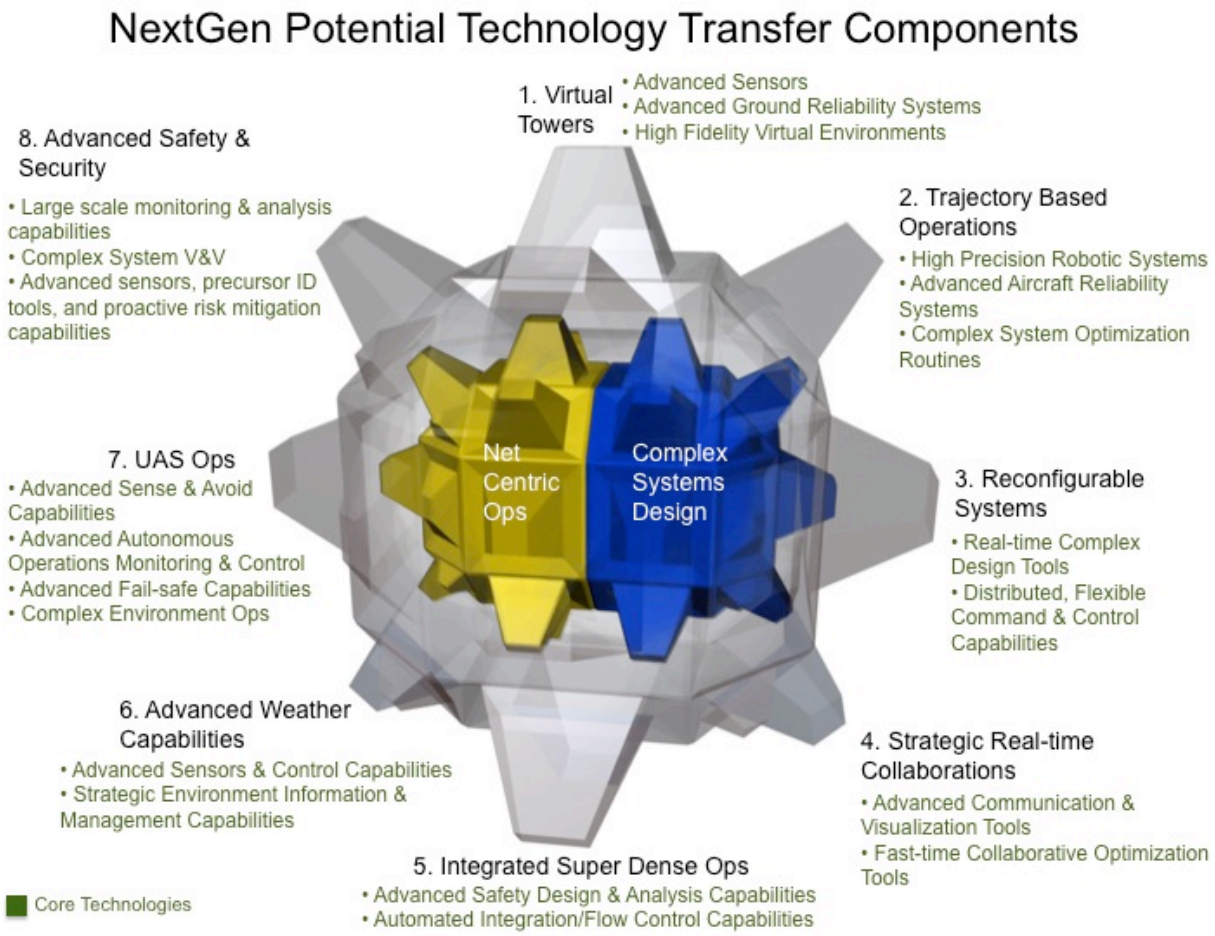
Figure 1: Overlapping Investments and R&D Needs



II. Ambitious Societal Goals

While change is likely to occur incrementally as each investment requires a complementary safety case, the overall goal of transforming the air transportation system requires a coordinated plan of research and development so that suitable technologies are available when needed. NextGen requires development of new automation, visualization, safety assurance, and collaboration technologies among others. The range of major technologies and their general applications to other industries are depicted below:

Figure 2: NextGen Advanced Technology Diagram



There are a number of underlying assumptions related to the benefits of this R&D:

- These new technologies are broadly adaptable to business, industry and society, and may confer benefits to other sectors of the economy
- Business, industry and government from other sectors are interested in these technologies
- These technologies may also reduce the need for physical travel and have positive social benefits in terms of reduced fuel consumption and pollution including greenhouse gas emissions

However, making the air transportation system more efficient may also increase the demand for air travel.

NextGen technology development also must consider a number of other costs and potential constraints. One major uncertainty is whether government funding is available for developing these types of technologies after meeting other societal needs. In turn, the need for such investment is also affected by factors including the following:

- Population and income growth which drive the demand for air travel
- Future fuel costs
- Environmental constraints
- Labor costs and productivity

The benefits of a new transportation system result from improved reliability, capacity, safety and environmental compatibility.

The ambitious goals in developing NextGen also show that there are potential benefits from transferring technology from other sectors into NextGen applications as well as transferring out NextGen technology to other sectors. These will be governed by factors including the value that could be created in other sectors, and the technology needs and uses in these sectors. In addition, this requires information on whether the technologies developed for NextGen can help other sectors. For example, are there general tools that can produce benefits elsewhere, and how can these applications be developed for uses other than NextGen? There are substantial opportunities that have been identified in conducting collaborative R&D with other agencies and programs in the federal government and the private sector.

III. Government Technology Investment Planning

The federal government manages an impressive technology development budget that spans many sectors of the economy and works across all agencies. In the Executive Branch, science and technology is organized under the National Science and Technology Council (NSTC), which has four primary committees including the following:

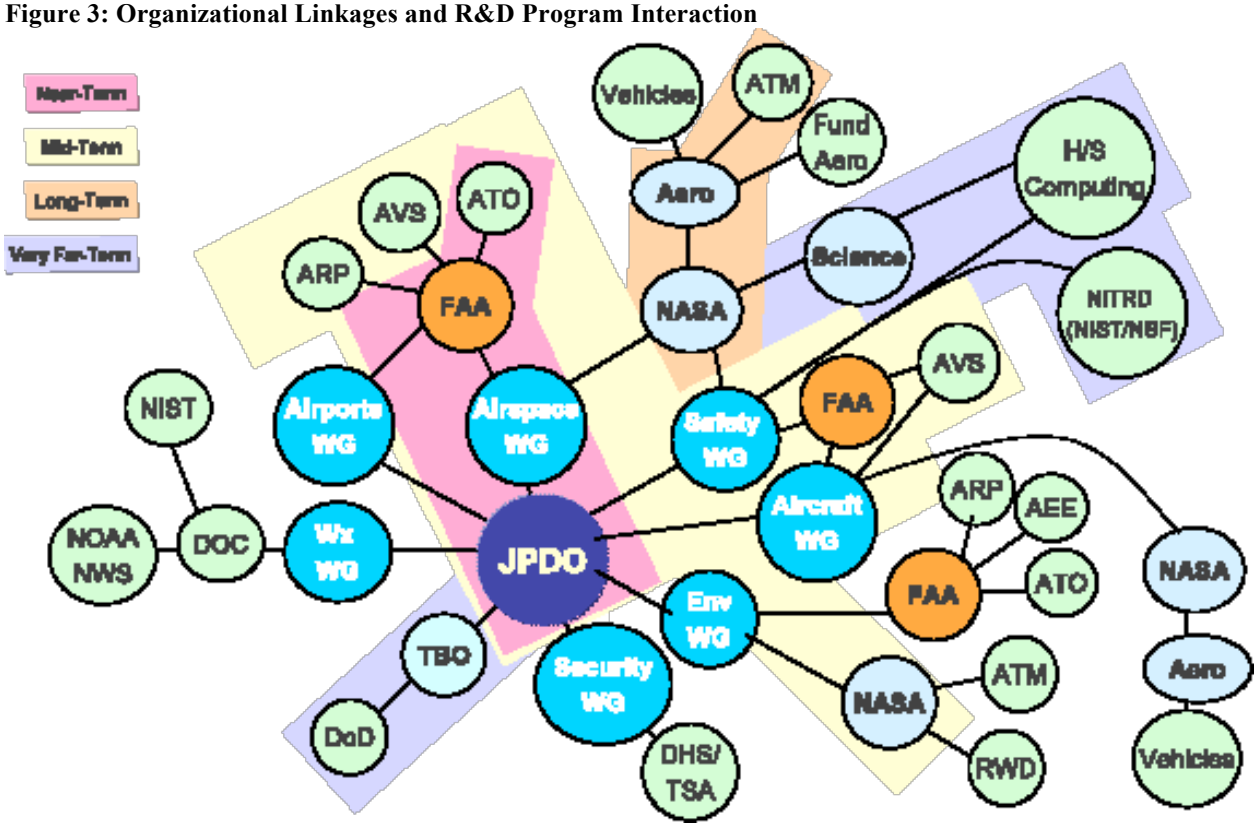
- Environment and Natural Resources
- Homeland and National Security
- Science
- Technology

All of these have R&D within their scope that will play a major role in the future air transportation system. For example, it is expected that NextGen will make substantial use of environmental and security technologies, among others.

The members of the NSTC include cabinet secretaries, administrators of independent agencies, and assistants to the President for national security, economic policy and domestic policy. NSTC also includes bodies such as the Council of Economic Advisors and the Office of Management and Budget. The NSTC Committee on Technology is the one that is perhaps most relevant for the JPDO. It has membership from all the partner agencies and other important bodies in the Executive Branch. It also oversees aeronautics research, and the OSTP lead for aeronautics research serves on the JPDO Senior Policy Committee.

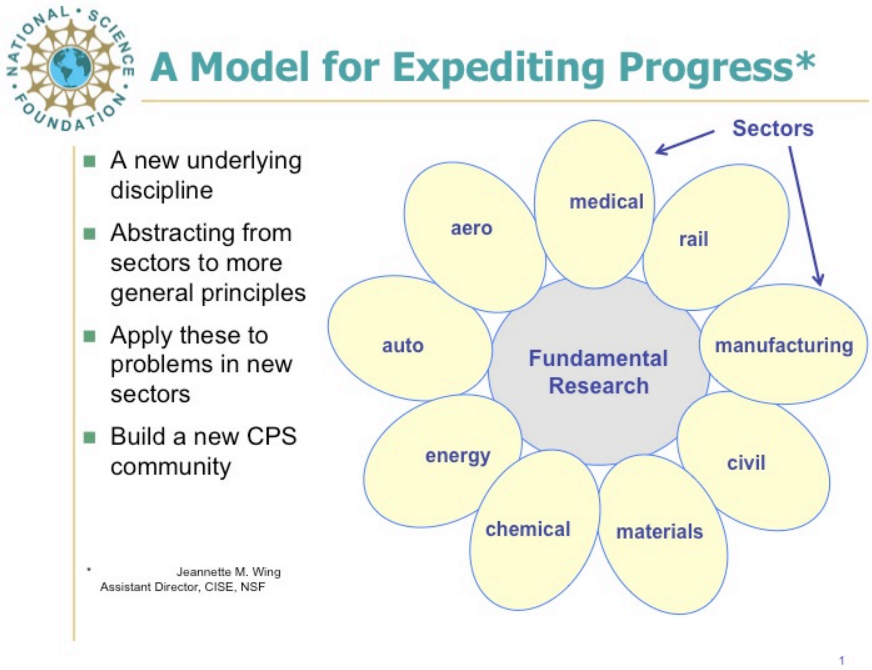
The JPDO functions as an R&D collaborative involving the partner agencies in developing the core technologies for NextGen. (The JPDO is a coordinating body; the research is conducted by or for the partner agencies.) NextGen technology needs can make use of technologies developed in other agencies. For example, much of a modern ATM system deals with networking and information technology, cyber-physical systems, and other related activities. Figure 3 illustrates the relationship between the JPDO's Working Groups, its partner agencies and some of these initiatives such as the Network and Information Technology Organization (NITRD) and the High Speed Computing Initiative at the tactical level. It is also clear that the main R&D performers are in the JPDO partner agencies and it is important to work with them to develop a NextGen R&D strategy and identify opportunities for collaboration. In addition, there is a need to work on certain core capabilities such as validation and verification of complex systems.

Figure 3: Organizational Linkages and R&D Program Interaction



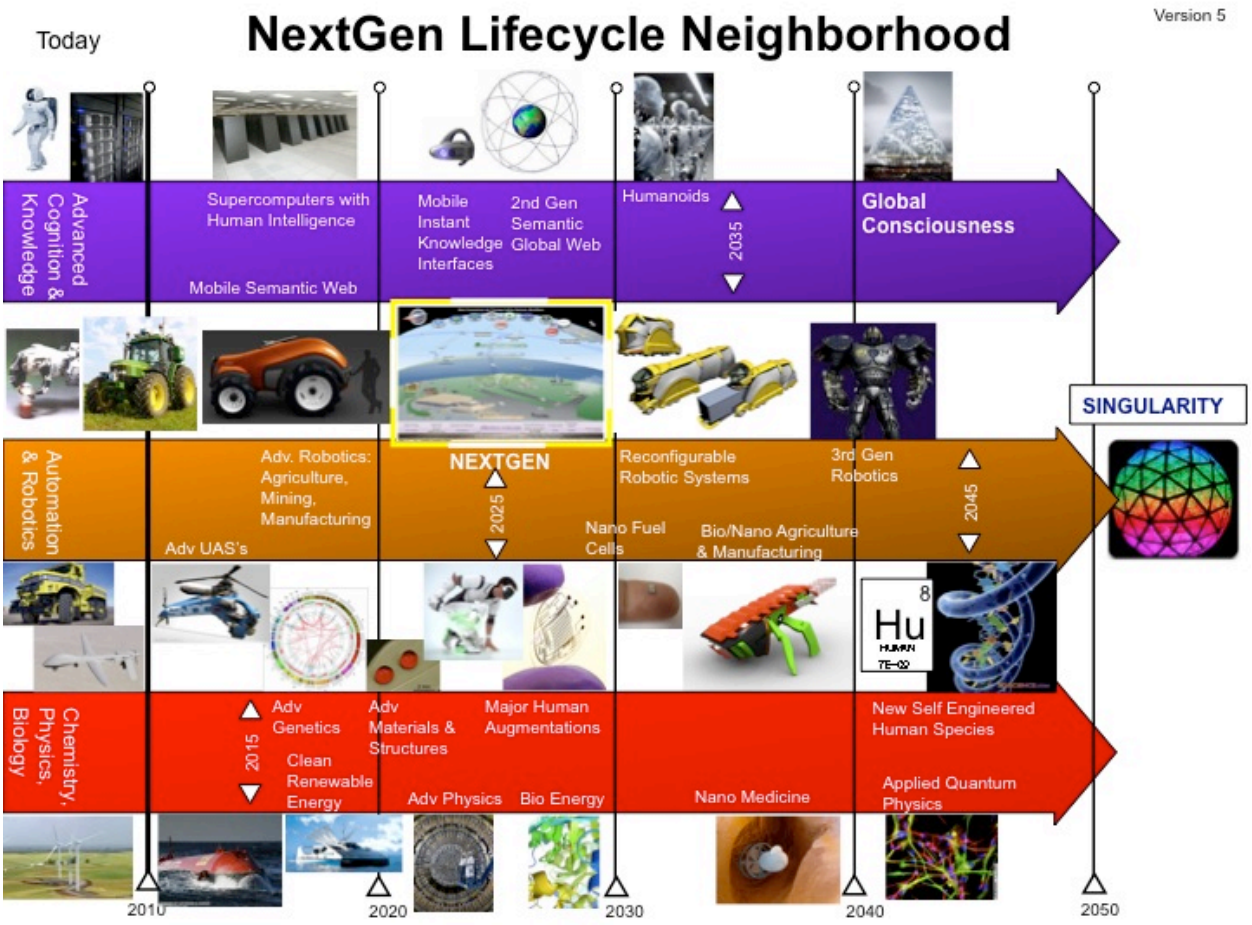
Furthermore the Cyber Physical Systems program has identified this top level strategic alignment between industries and domains to help expedite coordination and knowledge transfer:

Figure 4 A Model for Expediting Progress



The potential technology transfers in and out of NextGen for its full target deployment date of 2025 are immense. A notional view of the roadmap of future advanced technologies, both competing and enabling NextGen could look like this:

Figure 5: NextGen Technology Neighborhood



Due diligence in modeling of the benefits of NextGen and the impacts of various technologies require some level of estimating how other industries and fields will advance and their impacts to demand for NextGen.

IV Advanced Technology Universal Metrics

In order to assess the governments investments in advanced technologies and their collateral benefits across multiple domains a method of normalizing the values needs to be established. A standard set of metrics would enable a more systematic, transparent portfolio approach to evaluating the best return on investment.

There are several key challenges in undertaking a systematic evaluation approach:

- The federal government must regularly adjust budgets in the operations of the agencies and their associated research & development programs based on national mandates, the collaborative budget building processes, prevailing economic conditions, and global challenges.

- Agencies have limited and incomplete hierarchical, integrated, linkages of objectives to the Federal Government goals.

- Without an integrated hierarchy of objectives with associated metrics available for the agencies it is very difficult to normalize and evaluate the relative merits of one investment over another.

A first principles approach to these challenges are in the following way: In order to evaluate investment options across domains agencies must have explicit goals to measure them against. The goals for the United States Government are outlined in the Declaration of Independence:

*We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are **Life, Liberty**, and **the pursuit of Happiness**.*

These Rights are, in effect, the Goals of the Federal Government to provide or enable for each citizen. In order to conduct systematic portfolio analysis of these Goals two additional steps must be taken. The first is to breakdown these Rights in their major, discrete, and measurable objectives:

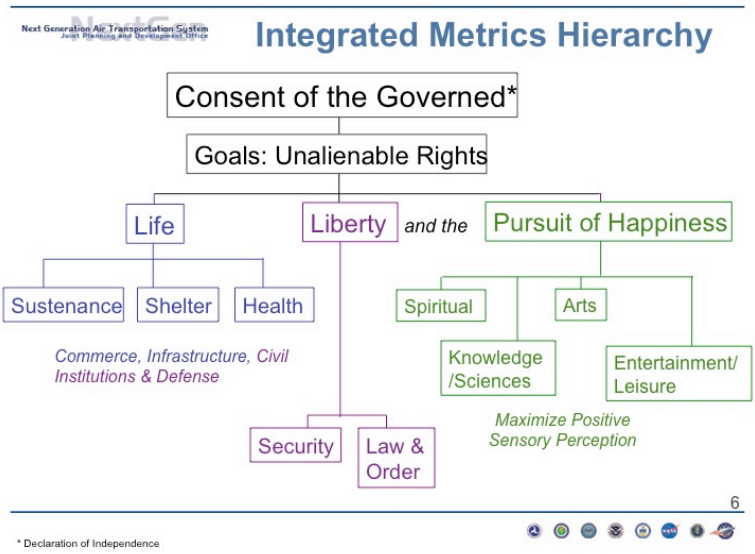
- **Life** is made up of the minimum following qualities:
  - Sustenance
  - Shelter
  - Health

- **Liberty** is made up of the minimum following qualities:
  - National Security
  - Law & Order

- **Pursuit of Happiness** is made up of the following broad qualities:
  - Spiritual
  - Knowledge/Sciences
  - Arts
  - Entertainment/Leisure

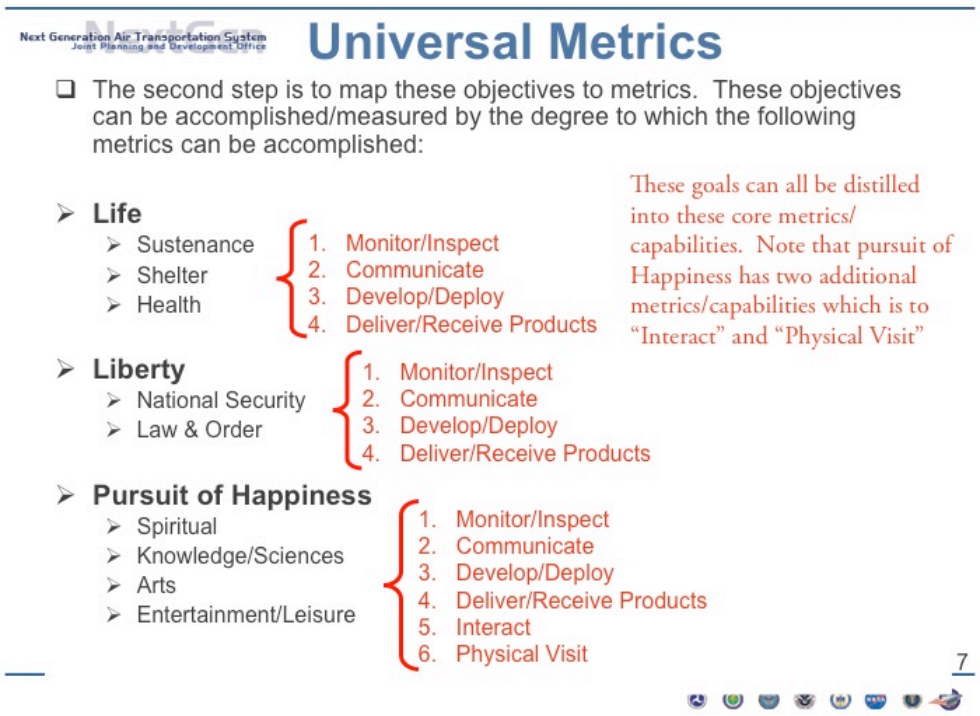
This perspective of the constitution provide the following organizational structure:

Figure 6 Integrated Metrics Hierarchy



The second step is to map these objectives to metrics. These objectives can be accomplished/measured by the degree to which the following metrics can be accomplished:

Figure 7 Universal Metrics Mapping



These metrics are defined as follows:

1. Monitor/Inspect - ability to fully monitor or inspect: entities, locations, or processes. Measurement: Number of inspections and Quality/Resolution per unit of time/cost.

2. Communicate - ability to exchange required information in the appropriate time frame & mediums. Measurement: Amount & Quality of data per unit of time/cost

3. Develop/Deploy - design, construct, test, and activate required products, processes and services at desired locations. Measurement: Amount & Quality per unit of time/cost.

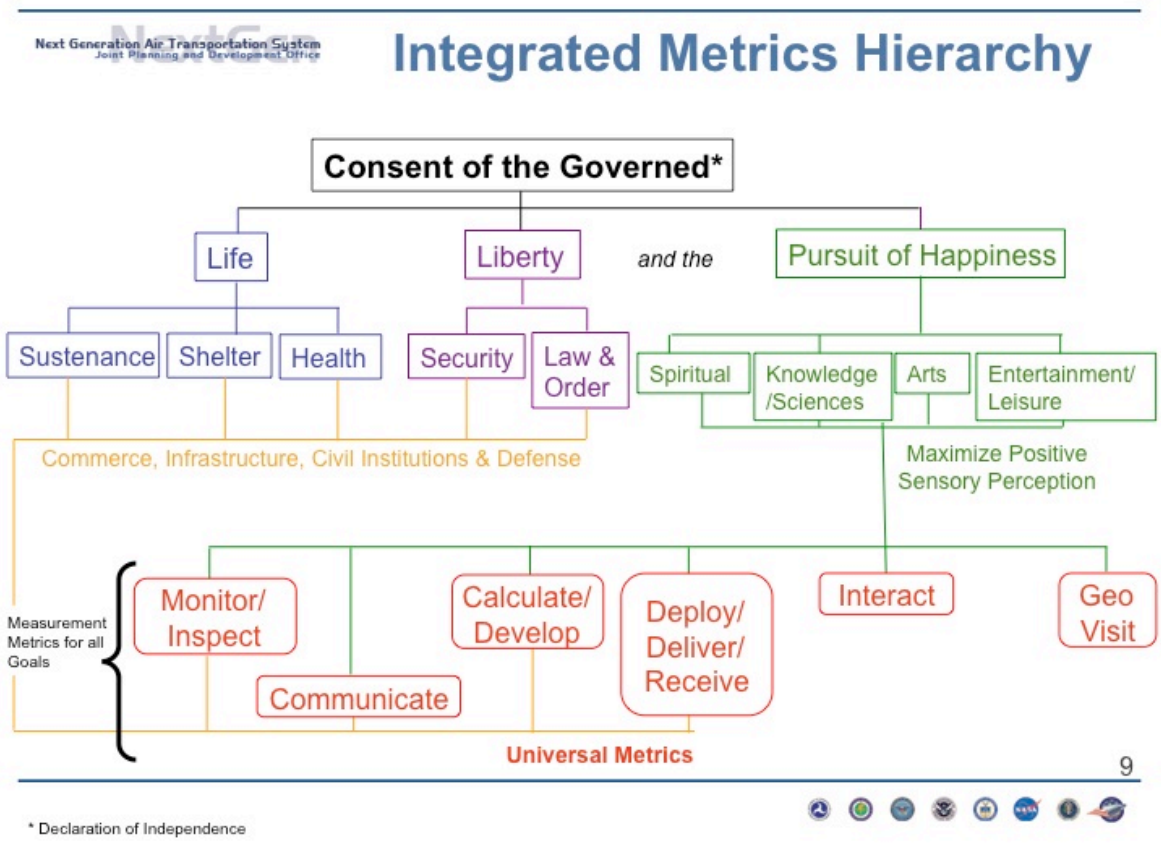
4. Deliver/Receive Products - transport of entities to target locations (for non leisure objectives). Measurement: Amount & Quality per unit of time/cost.

5. Interact - full sensory real-time interactions with living and non living systems. Measurement: ((Number of senses) x (quality) x (number of interactions per unit)) of time/cost

6. Physical Visit - physical presence at desired geographic locations for leisure purposes. Measurement: Availability, speed, and cost.

If we take the objectives and the metrics and align them we get the following linkage:

Figure 8 Linked Integrated Metrics Hierarchy



V Conclusion

NextGen will provide significant advancements in a broad range of technologies. These technologies have collateral benefits to other fields and industries. In order for the federal government to optimize its investments it needs a method to normalize these technology transfer benefits. We believe a set of universal metrics can be established based on first principles of the Unites States of American Constitution. This approach yields the following implications:

1. The goal of the federal government is to enable our citizens to Life, Liberty and the pursuit of Happiness

2. These goals can be broken down into the following objectives: Sustenance, Shelter, Health, Security, Law & Order, Spiritual, Sciences, Arts, Entertainment/Leisure.

3. These investments can be measured by the following universal metrics: monitor/inspect, communicate, develop/deploy, deliver/receive, interact and physical visit.

4. Using these Universal Metrics to map Agencies to the Federal Government's Goals enables one to normalize and evaluate all government investments and prioritize transparently based on standard portfolio management practices.